VOLTAGE EVALUATION AND VOLTAGE IMPROVEMENT

OF

RURAL DISTRIBUTION SYSTEMS

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INTRODUCTION

The questions often arise: "How can we evaluate voltage conditions on a system?" and "How should we improve voltage conditions on a system?" Voltage conditions may be readily evaluated by measuring voltage levels at specific points and then comparing the measured voltage levels with standards or requirements. Voltage improvements may be readily obtained by employing specific corrective measures at key locations. For purposes of discussion a system may be divided as follows: substations; distribution lines; distribution transformers and secondary services; and consumers' wiring. Those components of the system which affect the greatest number of consumers merit primary consideration.

SUBSTATIONS

Voltage level and voltage variation at a substation output affect the greatest number of consumers. Therefore, substations should be considered first. Voltage output requirements at a substation are 124 to 127 volts(1) during full load and 120 to 124 volts during light load. Voltage regulators should be employed to maintain these operating limits. Regulator input voltage must not exceed the limits of 114 volts minimum to 132 volts maximum.

Existing Condition	Suggested Remedy
No voltage control in the substation.	Install substation voltage regulators.
Incorrect balance-voltage of the regulator control. (Determined by a voltage(2) measurement at the test terminals on the regulator control panel. Take measurement with compensator controls set to zero.)	With the resistance and reactance compensator controls set at zero, adjust the voltage regulating relay to balance at 120.0 volts. Then adjust compensator for 124 to 127 volts during full load. (R = 6 and X = 2)
Low voltage during full load.	Increase the R & X settings of the compensator maintaining a 3:1 ratio of R:X.
High voltage during full load.	Decrease the R & X settings of the compensator maintaining a 3:1 ratio of R:X.
Regulator band width exceeds 2 volts or plus or minus one volt. (Determined from voltage(3) recording at the test terminals.)	Make necessary adjustments of the voltage regulating relay. (See manufacturer's instruction manual.)
Too high or too low input voltage to the substation regulators. (Indicated by the regulator going to full boost or to full buck.)	Adjust substation transformer taps to raise or lower the input voltage.
Voltage spread at the input to the regulator exceeds 18 volts. (Indicated by the regulator going to full boost and full buck.)	Negotiate with power supplier to obtain a better voltage supply.

DISTRIBUTION LINES

After necessary improvements have been made at the substation, the distribution lines should be considered next. Voltage level and voltage variation on any one distribution line affect a relatively large number of consumers. Voltage limits should be 127 volts maximum and 116 volts minimum, with a voltage drop along the line not exceeding 8 volts.

Existing Condition	Suggested Remedy
Voltage drop along distribution line less than 8 volts during the system seasonal peak. (Determined by recording substation output voltage and end of line voltage(3).)	No improvement is necessary. Record data for future reference.
Voltage drop along the distribution line exceeds 8 volts during the system seasonal peak. (Determined by recording substation output voltage and end of line voltage(3).)	Install line voltage regulator. Regulator should be located at a point approximately 1/3 the distance from the substation to the end of the line. The need for a system study may be indicated.
Too high or too low output voltage of line regulator. (Determined by voltage recording of the output voltage(3).)	Adjust regulator control as per instructions for substation regulators.
Input voltage to line regulator below 116 volts. (Determined by recording input voltage(3).)	Move regulator closer to the substation. Minimum input voltage should be 116 volts.
Voltage drop along the distribution line exceeds 16 volts during the system seasonal peak. (Determined by voltage recordings of substation output, input and output of line regulator, and at end of line(3).)	Rephasing or conversion is required. Two regulators will correct the excessive drop, but are only a stop-gap measure. Economic studies of line losses will almost always indicate that rephasing or conversion is required.

DISTRIBUTION TRANSFORMERS & SECONDARY SERVICES

Voltage level and voltage variation at the end of the secondary service (at meter socket) affect only one consumer. If the distribution line voltage is within the required voltage limits, the voltage spread at the consumer's meter socket should not exceed 17 volts. Operating voltage limits should be 110 volts minimum and 127 volts maximum. The maximum voltage drop through the transformer plus the secondary and service should not exceed 6 volts with approximately 3.5 volts through the transformer and 2.5 volts along the service conductors.

Existing Condition	Suggested Remedy
Voltage drop through transformer plus secondary and service exceeds 6 volts or approximately 5 percent. (Determined by a no-load and a full-load voltage reading at the meter socket.)	Decrease the length of secondary conductor by moving the transformer closer to the meter socket. (Most effective remedy.) OR Increase the size of secondary conductors. OR Convert any two-wire services to three-wire services.

Suggestion: Do not increase size of transformer unless the transformer is thermally overloaded. Changing the transformer taps should be considered a temporary expedient. This practice increases voltage spread and is not considered economical.

CONSUMER'S WIRING

Tolerable voltage limits at the point of utilization by equipment are 107 volts minimum and 127 volts maximum. These limits should never be exceeded. Three volts drop, or approximately 3 percent, should be a maximum in the consumer's wiring. Voltage drop in the consumer's wiring may be determined by taking no-load and full-load voltage readings at the point of utilization. It is the consumer's responsibility to correct excessive voltage drop in his wiring. Utilization voltage can be maintained within 107 to 127 volts if the system voltage limits described herein are not exceeded.

Notes:

(1) All voltage values are referred to a 120-volt base.

(2) Indicating voltmeters used to check regulator control adjustments should have a stated accuracy of plus or minus 3/4 of 1% of full scale.

(3) Recording voltmeters used for these purposes should have a stated accuracy within plus or minus 1% of full scale.

Reference

Voltage Levels On Rural Distribution Systems, March 1952, U.S.D.A., Rural Electrification Administration, Technical Standards Division, Washington 25, D. C.